Spierling.

Investigation Of The Power Requirements Of A Paper Manufactory.

INVESTIGATION

OF THE

POWER REQUIREMENTS

OF A

PAPER MANUFACTORY

BY

ARTHUR OTTO SPIERLING

B. S., UNIVERSITY OF ILLINOIS, 1910

THESIS

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE

DEGREE OF
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THE GRADUATE SCHOOL

May 3 1916

I HEREBY RECOMMEND THAT THE THESIS PREPARED BY

Arthur Otto Spierling

ENTITLED Investigation of the Power Requirements of a Paper Manufactory.

BE ACCEPTED AS FULFILLING THIS PART ON THE REQUIREMENTS FOR THE PROFESSIONAL DEGREE OF Mechanical Engineer.

C. R. Richards

Head of Department of Mech. Engineering

Recommendation concurred in:

C. R. Richards
Edward C. Schmidt
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INVESTIGATION

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INTRODUCTION

In this great age of refinement in production, the mind of the paper manufacturer has been intent upon the process of making paper. So rapid and great have been the strides in this industry that in trying to keep apace with the times, such departments as the power plant although essential adjuncts to the industry, have been relegated to a secondary or minor consideration.

This is truly remarkable when one stops to consider the fact that the coal bill forms a very appreciable percentage of the total cost of making paper. The steam generated by the fuel is used in practically every step in the process. The raw wood or rags, whichever the paper is to be made from, is cooked with steam, the screens used for separating the pulp from the foreign matter are kept clean with steam. In the bleach chests, we find that the pulp is heated with steam that the pulp ~~might~~ may bleach faster and better. Steam is also used for making the size and for heating the pulp, in the beating engines, and at the end of the process, steam is used in enormous quantities for the drying of the wet paper.

Thus the great importance of steam in this process can be readily understood, especially so when it is stated that there is no practical substitute for this agent.

Today no one problem is causing the manufacturer more anxiety and worry than that of cost. Without an exact knowledge of the

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INTRODUCTION (Con.)

costs of production, he can not establish a sound price. Keeping this in mind, we will turn toward an inspection of the equipment and the study of the operating conditions of that portion of a paper mill devoted to the generation and utilization of steam.

Note:

The following investigation was made in a New England paper mill having a daily capacity of 16,000 pounds of soda fibre, 28,000 pounds of sulphite fibre and for coating 200,000 pounds of paper.

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PURPOSE AND SCOPE OF THIS INVESTIGATION

The purpose of this investigation was as follows:

(a) To study the design of the equipment and ascertain the physical condition of the various pieces of apparatus in the boiler plant and engine room.

(b) To determine the efficiency with which the boiler plant was operated in view of making recommendations whereby controll - able losses might be reduced.

(c) To determine the efficiency with which the exhaust steam is utilized in the feed water heater, together with the fuel saving which is effected by the economizer which utilizes the waste gases from a black ash plant.

(d) To obtain cards from the engines indicating the horse-power developed and to study the shape of these cards with a view of offering recommendations regarding the use of steam in these engines.

(e) To investigate the utilization of steam for the various purposes throughout the mill, such as sulphite digesters, soda digesters, bleaching tanks, etc., giving particular attention to the exhaust steam which is not returned to the feed water heater.

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EQUIPMENT FOR THE GENERATION AND UTILIZATION OF STEAM.

The equipment for the generation of steam in this mill consisted of five Dean & Main 400 H.P. return tubular boilers, set in a continous battery, 90" in diameter and containing 260 - 3" tubes, 20' long. These boilers are equipped with flat grates having an area of 69.4 square feet per boiler. The exterior of the boiler house and fronts of the boilers are shown in photographs Nos. 1 and 2 appended to this report.

Draft Equipment. Natural draft for boilers, together with the black ash incinerator was furnished by a round brick stack 8 feet in diameter and 175 feet high. The damper in the main flue from the boilers and black ash incinerator was equipped with a Spencer automatic damper regulator for controlling the intensity of the draft in accordance with fluctuations in the steam pressure. This apparatus was not used at the time of this inspection as the flue from the black ash plant is connected beyond the main damper, which would render it impossible to reduce the draft in case of high steam pressure by this means at the times when the black ash incinerator is operated. The draft was, therefore, controlled by the hand dampers on the individual boilers.

Economizer Equipment. The gases from the black ash incinerator passed to the main flue through a Green economizer having a heating surface of 2016 square feet.

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EQUIPMENT FOR THE GENERATION AND UTILIZATION

OF STEAM - - (CON.)

Boiler Feed Water Heater and Pumps. Returns from the mill exhaust steam were passed through a National feed water heater of the closed type, rated at 2500 H.P.

Boiler feed water was pumped through the above heater by a Deane outside packed duplex steam pump 14 x 8 x 12 inches. This pump is installed in duplicate. The locations of the pumps and feed water heater are shown in photograph No. 3.

Coal and Ash Handling. Coal was delivered from cars to outside storage and reclaimed from this storage pile as needed in the boiler room by wheelbarrows. The ashes were removed from the pits in a similar manner.

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1V

FUEL

The fuel being used at this plant was mine run coal from the Pennsylvania semi-bituminous field. This coal was supplied by rail shipments through the Russell Coal Company at a price of $4.50 per ton of 2240 pounds.

The analysis of a sample of this fuel, taken at the time of this investigation, indicates that this coal is of only a fair quality. The percentage of ash content is much higher than should be expected of this grade of fuel coming from the above named locality.

Taking into consideration the price being paid for this fuel, it is believed that it is possible to obtain a much better quality of fuel for the same expenditure. It is therefore recommended that the coal should be purchased on the open market on the basis of quality.

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INSTRUMENTS FOR TESTING AND THEIR CALIBRATION

Care was taken that the instruments used in all tests were carefully calibrated in order that true readings should be obtained. The thermometers were checked against a standard thermometer which had been calibrated by the Bureau of Standards at Washington, D.C. The pressure gages were checked on a standard dead weight tester.

Sampling of the boiler flue gases was done by a Billings Improved Orsat, which automatically takes an average sample over any range for which the instrument may be set. The Orsat part of this instrument is operated in a similar manner to the ordinary type. It may be well to add that the samples were taken over mercury rather than water.

For measuring the quantity of steam supplied to the various departments throughout the mill, a Gebhardt Steam Meter was used. This meter is of the indicating type and it was therefore necessary that frequent and regular readings be taken in order to determine the steam consumption. In measuring the steam flow to the reciprocating engines, the meter was inserted into the steam line as far away from the engine as was practical. This was done in order to minimize the effect of steam pulsations.

A test of the accuracy of this meter is shown in tabular form.

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TESTS IN BOILER PLANT

The principal tests which were conducted in the boiler plant were (a) a series of combustion tests and (b) a series of firing tests.

(a) Combustion Tests. Two combustion tests comprising observations on drafts, temperatures, flue gas analyses and weights of coal fired were conducted on July 22 and 23. Boiler No. 1 was selected for the purpose of the first test. To obtain further data concerning the operation of the boiler plant a combustion test, including two boilers, was made on the second day. All observations were made at ten minute intervals and the half-hourly averages are herewith presented. A sample of the coal used in these tests was secured before weighing. The ash sample was taken at the regular fire cleaning period. Results are shown in Table No. 1.

Test on No. 1 Boiler. The test on No. 1 boiler shows that it was being operated at an unusually low per cent of its rated capacity. This fact should very probably be attributed to the high percentage of ash in the coal. As the ashes were permitted to collect upon the grates under the fire, until the regular cleaning period which came only twice in twenty-four hours, an exceptionally high draft over the fire was required for combustion. In order to obtain a higher rating, it would be necessary either to use a superior grade of coal, to install a different type of grate permitting the removal of ashes without interfering with the operation of the boiler, or to increase the

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number of cleaning periods when systematizing the method of firing.

The per cent of carbon dioxide in the flue gas averaged 8.4 per cent for the test. This is very low considering the fact that the fires were not being attended at very frequent intervals. Improper damper regulation by the individial firemen was undoubtedly the cause of this low average.

The low temperature of the escaping flue gases (440°F) cannot be credited to the heat absorbing power of the boiler so much as to the low rating at which the boiler was being operated. This temperature would have probably been considerably higher had the fire been forced to maintain the rated capacity of the boiler.

Test on Nos. 1 and 2 Boilers. As the waste gases from a black ash incinerator entered the flue at the extreme end, mixing with products of combustion from the boilers, it was deemed advisable to conduct a test on a battery of only two boilers from which to interpret the general operation of the boiler plant.

During this test on the two boilers the fireman seemed to be doing better work which was evidenced by the decrease in the average percentage air excess which indicated that the coal was being more efficiently burned. As a fairly high average efficiency was maintained and a greater weight of coal was burned, it was evident that a higher rating was developed in the boiler. However, the same defects in operation as noted in the previous test were apparent from time to time. See Tables Nos. 1 and 11.

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(b) Firing Test. To determine the rate and amount of work done by each fireman, a firing test was made on August 15, During this test which covered a period of 10.25 hours, every attention given to each boiler was recorded. All coal consumed during the test was weighed upon a platform scale which had been checked with test weights before being used. In order to determine whether any variation in the quality of the coal occurred between the fuel supplied during this test and those which had been made on previous days, a continuous sample was taken. It will be noted from the tabular data appended herewith that the coal was running fairly uniform as there was a difference of less than 0.5 per cent in the ash content. The data which was secured during this test with reference to the manipulation of the fires is submitted in Table No. III which is self-explanatory.

At the time these tests were being conducted the men employed in the boiler house were in a state of unrest as a result of having demanded an increase in wages. Although it would seem that due to this question arising the men would give increased attention to their duties at least during the period of testing, such was not the case. Little or no interest was shown by the firemen in the work, The steam pressure was unnecessarily permitted to fluctuate over a wide range. Safety valves were permitted to blow for many minutes, no attempt being made to stop this waste by checking the dampers. The ash pits were permitted to become choked with fine ashes, cutting off the proper air supply.

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Heater and Economizer Operation. The temperature of the water leaving the feed water heater during these tests was especially high as will be noted from the figures of 241°F. and 243°F. as given in the accompanying table. This temperature is undoubtedly higher than is found in the normal operation of the plant due to the fact that the relief valve on the heater was out of order and a pressure of 20 pounds was maintained on the line from the coating mill engine exhaust which is connected both to the coating mill and the heater. The reducing valve on the live steam line was open continually and such a high pressure was maintained that a large amount of steam escaped through the heater relief. Under normal operating conditions this temperature would average between 200°F. and 210°F.

The differences in temperature between the water leaving the feed water heater and the economizer represent the amount of heat recovered from the incinerator gases. The rise of temperature in the feed water in passing through the economizer was very low being between 4°F. to 14°F. This small increase was due, first, to the fact that a temperature of the water entering was very high and, therefore, the heat absorption will not be as great as with colder water, and second, the rise under normal conditions will not be as high as would be expected in an economizer designed to recover heat from all the flue gases produced in a boiler plant. The economizer has a heating surface of about 2000 square feet which would be suited in ordinary economizer practice for a plant of about 600 horse power.

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VII

CHANGES IN BOILER PLANT EQUIPMENT

Referring to the matter of changing the furnace equipment in the boiler plant, an installation of shaking grates is the first recommendation. The very best grates of this type can be purchased for about $5.00 per square foot, which would represent an investment of approximately $1875.00. While it is difficult to give an estimate of the fuel saving which might be effected by the use of shaking grates, it is believed that this would annually equal the amount of the investment.

The matter of the installation of stokers in this plant has been investigated and although the original investment in this equipment together with the charges for operation are quite high, this matter should receive careful consideration. This is particularly true if future labor troubles are anticipated or if very extensive additions are contemplated to the present boiler capacity. The most satisfactory stoker installation under the present boiler settings would be either an inclined type such as the Taylor or Riley underfeed stoker or a horizontal type such as the Jones under-feed stoker. The cost of installation and operation of the two types of stokers mentioned above would be approximately as follows:

	Inclined Under-feed (Riley)	Horizontal Under-feed (Jones)
Initial cost, installed	$12,000	$9,500
Cost of Operation		
Fixed charges at 13%	1,560	1,235

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Steam chargeable to stoker operation	800	800
Miscellaneous supplies	50	50

Provided coal handling equipment is installed with overhead bunkers for feeding fuel directly to the stoker hoppers, two firemen per shift can be eliminated, making a total saving in labor of about $5,200 per year. If the coal is wheeled into the boiler room and shoveled by hand into the stoker hoppers, one man per shift may be eliminated which is equivalent to a labor saving of about $2,600. It is difficult to estimate what the actual coal saving would amount to in case mechanical stokers were installed although this item can easily amount to five per cent of the annual bill for fuel.

The matter of coal handling equipment for the boiler plant was carefully investigated and several forms of apparatus have received consideration. A traveling crane, electrically operated, with a grab bucket which will take coal from the cars and deposit the same in the storage or reclaim from the storage or handle directly from the cars to the boiler room seems to be the most feasible and least expensive. If stokers are not installed it will be necessary to erect at least four hoppers outside of the boiler room in which the coal would be deposited by the locomotive crane. These hoppers will feed directly to the boiler room floor at various points along the boiler fronts. If the stokers are installed it is recommended that an equipment of overhead bunkers together with a traveling hopper and crusher also be installed. The approximate cost of this equipment, together

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with the operating expenses, is about as follows:

Coal handling equipment with outside hoppers

Initial cost including crane, trestle and hoppers		$7900.
Cost of operation		
Fixed charges at 13 per cent	$1027.	
Labor (1 man at $3.00 per day) (3 men at $2.00 per day)	2700.	
Power, 25 kilowatts, 1800 hours per year at 2¢ per kilowatt	900.	$4627.

Coal handling equipment with overhead bunkers

Initial cost including crane, trestle, bunkers and crusher		12000.
Cost of operation		
Fixed charges at 13 per cent	$1560.	
Labor as above	2700.	
Power as above	900.	5260.

Present charge for labor handling coal $6522.

The above figures indicate that a considerable saving can be effected by coal handling equipment and it is urged that this receive careful consideration. This matter is particularly important in view of the fact that the locomotive crane may be used for handling other materials in the yard.

VIII

DISTRIBUTION OF STEAM.

The distribution of steam has been grouped under two general divisions-

(a) Steam used for power

(b) Steam used for manufacturing purposes.

In this mill as in other paper mills, the steam used for power engines is further used in supplying heat for manufacturing purposes. Should the engines be of uneconomical design or operating under poor conditions, the steam necessary for power purposes will exceed the mill requirements for low pressure steam and the excess will be wasted. It is therefore important that a careful study be made of these units.

ENGINE TESTS

On August 22nd and 23rd, the four principal engines were tested for general performance with a standard engine indicator. Several diagrams were taken from each engine under different conditions of load and steam pressure. Typical cards showing the general operation of the engines were selected from each set of diagrams and are herewith presented.

On November 11th and 25th, steam consumption tests were made upon the Filer and Stowell twin engine driving the Coating Mill, and on the Fitchburg engine driving the Wood Room using a Gebhardt steam meter. Indicator cards were taken simultaneously with the meter reading and from these the steam consumption per indicated horse power has been computed. Knowing the conditions under which the two Harris-Corliss engines were operating, it was deemed sufficiently accurate for

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the purpose of this investigation to approximate the steam economy of these engines.

None of the diagrams indicate that there is anything radically wrong with any of the engines. An average load was being carried by each engine with the exception of the Harris-Corliss engine No. 2 which drives the No. 2 mill. The load on this engine could, if desired, be increased to approximately double that which was being carried at the time of the test with a material increase in economy per unit of power. The valves are all set approximately right to perform their proper functions. It would hardly seem advisable to make any adjustment of the valve rods unless it were done with the aid of an engine indicator.

It is, however possible to make a close inspection of the pistons, cylinders, valves and valve seats of the engines on a day that the engines are not in use without affecting the adjustment of the valve gear. After these have been carefully examined as to their physical condition they should be tested for steam leakage. With the cylinder head removed and engine blocked with piston in the middle of its stroke, the piston is tested for leakage by admitting steam to the crank end and observing from the head end the amount of escaping steam. The valves should be tested, the engine blocked and the throttle cracked open, by keeping the valves closed and observing the extent of leakage into the cylinder. It would be advisable for the operating engineer to make such an inspection once every month on each engine in order to keep the engines in condition for economical operation.

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STEAM DISTRIBUTION FOR MANUFACTURING PURPOSES

Aside from that consumed by the engines, steam was distributed and utilized for the following purposes:

(a) Soda Digesters. Two vertical cylindrical soda digesters used live steam which was maintained at a pressure less than 110 lbs. per square inch by means of a regulating valve located on the steam main. At the time of testing, the digesters were being operated at an average rate of four cooks per twenty-four hours and an average weight of 3485 pounds of bleached pulp was being obtained per cook.

On August 28, a steam consumption test was made on No.10 digester covering a period of one complete cook..Steam meter readings were taken at ten minute intervals and from these the total steam consumption of 12,227 pounds or 3.51 pounds of steam per pound of bleached pulp was computed.

(b) Sulphite Digesters. Eight rotary globe sulphite digesters, each 11 feet in diameter on the outside and about 10 feet in diameter on the inside, were supplied with live steam reduced to a pressure of 90 lbs. per sq. in. At the time these tests were made the digesters were being operated at an average rate of 16 cooks per 24 hours and an average weight of 1231 pounds of bleached pulp was being obtained per cook.

On August 22, a steam consumption test on digester No. 7 was made for a period of one cook. This test showed a total steam consumption of 8,027 pounds which would be about 4.38 pounds of steam per pound of bleached pulp.

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(C) Yaryan Evaporator. One triple-effect evaporator used for concentrating the black liquor was supplied with live steam at a reduced pressure of 40 pounds per square inch. To determine the approximate amount of liquor passing through the evaporator per hour a test was made on August 28. The supply pipe from the wash pans was shut off for a period of two hours and forty-five minutes and by measuring the initial and final heights of the liquor in the reservoir from which the evaporator was supplied, the volume of liquor passing into the evaporator during this time has been computed. Throughout the test readings were taken of the specific gravity of the liquor before and after going through the evaporator and from this data the weight of water distilled from the liquor has been determined.

An evaporation of about 2.4 pounds of water per pound of steam is considered a fair average for this type of apparatus. On this basis the approximate steam consumption of the evaporator would be 2,045 pounds per hour which amounts to about 5.87 pounds of steam per pound of bleached soda pulp.

(d) Bleach Tanks. Six bleach tanks and two chemical tanks were heated by means of live steam. To determine the weight of steam used in this process a steam meter was fitted to the main supply pipe and readings were taken on August 10, during the heating period on two sulphite bleach tanks.

At the time of testing an average charge of each bleach tank yielded about 1923 pounds of bleached pulp. The test showed a steam

consumption of 987 pounds per tank which expressed in pounds per pounds of bleached pulp amounts to 0.51.

(e) Paper Machines. Four paper machines, three of which used some exhaust steam, were supplied with live steam. The pressure of the exhaust steam at the dryers averaged about eight pounds per square inch and the pressure of the live steam on the finishing dryers was regulated by hand valves according to the quality of the paper being made.

In order to determine the steam consumption of these machines, a meter was attached to the pipe furnishing each machine room with live steam. On August 29, tests were made on Nos.1 and 2 paper machines covering a period of 7 hours during which the combined rate at which the two machines were being operated was 1262 pounds of paper per hour. As these machines utilized the exhaust steam for the larger Harris-Corliss engine, the total steam consumption of the machines was approximately 3468 pounds of live steam per hour as shown by the meter, plus 3512 pounds of exhaust steam supplied through the engine. This means a total steam consumption of 3,980 pounds per hour or 5.53 pounds of steam per pound of paper.

On September 3, a test was made on Nos. 3 and 4 paper machines, the latter being operated wholly with live steam. As the steam pipe on which the meter was connected supplied the small Harris-Corliss engine in addition to supplying the machines and as the exhaust from this engine was utilized by the No.3 paper machine, the meter readings were a direct measure of the total steam being used by the two paper

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machines. The test showed a total steam consumption of 4756 pounds per hour with the machine operating at a combined rate of 1137 pounds of paper per hour, or an average consumption of 4.18 pounds of steam per pound of paper. The proportion of live steam used by the dryers was obtained by subtracting the approximate weight of the steam exhausted from the small Harris-Corliss engine from the total steam metered.

Tabulations of results of these tests showing the distribution of steam throughout the mill together with detailed figures for the cost of steam are given in Tables 1V, V and V1.

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IX

DISCUSSION OF ENGINE AND PROCESS TESTS

A survey of the plant noting the great amount of excess steam escaping from the various relief valves, is very indicative that a material saving in steam, can be made. As the engine cards show but little opportunity for any great increase in economy that might be effected by changes in the valve settings, other means must be sought in order to reduce the total steam consumption of these units.

Two general methods are suggested as a means of increasing the overall economy of the steam distribution.

1. Increased Steam Pressure.

If the steam were supplied to the engines at an increased pressure, a very appreciable decrease in the steam consumption would be the result.

The investigation shows that the boilers in this plant are operating on an average steam pressure of 105 pounds gage. As these particular boilers were designed for 150 pounds working pressure and as the insurance policy permits the safety valves to be set at 130 pounds gage, it is safely possible to increase the operating pressure.

2. Rearrangement of the Load

If the steam pressure were first increased to a minimum of 125 pounds, it would then be possible to make a satisfactory re - arrangement of the mill load which would materially increase the over-

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all economy.

The following changes are thereafter recommended:

(a) That a 75 K.W.D.C. generator be added to the load of the engine known as No. 2. Harris-Corliss Engine.

(b) That the lighting load of the entire mill be put on this generator thereby relieving the Filer and Stowell Twin Engine.

(c) That a 300 K.W.D.C. generator be substituted for one of the 150 K.W. generators now being driven by the Filer and Stowell Engine.

(d) That the second 150 K.W. generator on the Filer and Stowell Engine be arranged with a clutch so as to make it possible to completely disengage this generator from the engine.

(e) That the replaced 150 K.W.D.C. generator be turned into a motor and used for driving Paper Machines Nos. 3 and 4 with their corresponding beaters, refining engines and pumps. This would replace the old D.C.motor now driving this beater room and the No. 1 Harris Engine.

(f) That the exhaust from No. 2 Harris-Corliss Engine and the excess from the Filer and Stowell Engine be piped as to be available for use in the dryers on all the paper machines, and for the boiler feed water heater.

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(g) That the condensation from the paper machines and steam headers be collected into one or two large receiver tanks vented to the atmosphere, and pumped from these tanks either to those parts of the process requiring hot water or back to the feed water heater.

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RECOMMENDATIONS AND CONCLUSIONS.

In conclusion the following recommendations are offered in regard to a more economical operation of this steam plant:

1. A competent person of executive ability should be in charge of the boiler house and steam distribution.

2. If it is intended to continue using the same grade of coal which is high in ash, some means should be provided for the removal of ashes from the grates without seriously interfering with the operation of the boiler.

3. Until such changes are made, the number of cleaning periods should be increased to three or possibly four per twenty-four hours. The frequency of these periods should be optional with the head fireman as the number of cleanouts necessary will change with the various grades of coal.

4. The draft on all boilers should be automatically controlled in order to obtain a more constant steam pressure with a minimum amount of effort on the part of the firemen. This would prevent the safety valves from blowing an unnecessary length of time.

5. Ashpits should be clean at all times. This is exceptionally important in the boiler plant as the space between the grates and the bottom of the ashpit is small. By permitting ashes to collect in these pits combustion of the coal is retarded and there is a likelihood of the grates being burned.

6. All steam gauges used on the boilers should be overhauled

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at regular intervals and set to read correctly.

7. The inspection of the engines as described in another section of this report should be made by the operating engineer.

8. Careful attention should be given to all waste due to exhaust steam and hot condensed water which are now rejected to the river. A very marked saving in the fuel account can be effected by returning the exhaust steam to the heater and using the hot water for various purposes throughout the mill.

9. The steam pressure should be raised to a minimum of 125 pounds gage.

10. Changes should be made in the distribution of the load along the lines herein suggested.

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TABLE NO. 1.

1. No. of boiler	1	1 and 2
2. Date of test	July 22	July 23
3. Time	8:30 A.M. to 8:30 P.M.	9:00 A.M. to 5:00 P.M.
4. Duration of test, hours	12	8
Dimensions and Proportions		
5. Grate area per boiler, sq. ft.	69.4	69.4
6. Builder's rating, horse power	400	400
Average Pressures		
7. Steam pressure, lbs. per sq.in.	104	103
8. Draft over fire, inches of water	0.56	0.57
9. Draft in flue, inches of water	0.64	0.69
Average Temperatures		
10. Of boiler room, °F.	95	96
11. Of feed water leaving heater, °F	241	243
12. Of feed water leaving economizer, °F	245	257
13. Of flue gas, °F.	440	479
Fuel		
14. Total weight of coal fires, pounds	12,819	19,481
15. Weight of coal fired per boiler per hour, lbs.	1,068	1,218
16. Weight of coal fired per sq.ft.of grate per hour, lbs.	15.4	17.5
Attentions to Fires		
17. Average number of firings per door per hour	3.0	3.4
18. Average number of slicings and levelings per door per hour	3.1	2.5

TABLE NO. 1

Proximate Analysis of Coal		
19. Moisture	1.21	
20. Volatile Matter	20.11	
21. Fixed Carbon	65.83	
22. Ash	12.85	
	100.00	
23. Sulphur	1.80	
24. B. t. u.	13342	
Analysis of Ash and Refuse		
25. Combustible	16.74	
26. Earthy Matter	83.26	
	100.00	
Analysis of Flue Gases, Per cent by volume		
27. Carbon dioxide (CO_2)	8.4	9.8
28. Oxygen (O)	11.0	9.4
29. Carbon monoxide (CO)	0.0	0.0
30. Nitrogen, by difference (N)	80.6	80.8
31. Air excess, per cent	109	80
Distribution of heat in per cent of heating value of coal		
32. Heat carried away in dry flue gases	13.5	12.9
33. Loss due to formation of carbon monoxide	0.0	0.0
34. Loss due to moisture and hydrogen in coal	3.3	3.3
35. Loss due to unconsumed carbon in ash pit refuse	2.8	2.8
36. Loss due to radiation (assumed)	8.0 to 12.0	8.0 to 12.0
37. Boiler efficiency by difference	68.4 to 72.4	69.0 to 73.0

TABLE NO. 1

Capacity		
38. Average horse power developed (Calulated from coal consumption and boiler efficiency, by difference)	298	340
39. Per cent of rating develped.	74.5	85

TABLE NO. 11

Boilers Nos. 1 and 2

Time		Draft, inches of water		Feed Water Temp. °F.		Attention to fires		Steam Pressure Lbs. per Sq. in.
From	To	Over Fire	In flue	Leaving heater	Leaving economizer	Firing	Slicing and Leveling	
9:00	9:30	.62	.71	242	261	12	9	98
9:30	10:00	.65	.71	243	260	12	9	104
10:00	10:30	.56	.69	248	269	6	6	107
10:30	11:00	.56	.68	244	267	9	9	101
11:00	11:30	.58	.70	243	262	0	0	104
11:30	12:00	.67	.74	241	261	12	6	110
12;00	12:30	.46	.64	242	267	3	6	102
12:30	1:00	.50	.65	244	268	9	0	108
1:00	1:30	.58	.65	240	267	28	26	89
1:30	2:00	.54	.66	234	245	0	6	98
2:00	2:30	.43	.62	242	252	4	3	98
2:30	3:00	.56	.67	244	254	5	3	113
3:00	3:30	.56	.70	242	247	12	15	100
3:30	4:00	.55	.70	245	245	15	9	99
4:00	4:30	.60	.70	246	245	18	6	108
4:30	5:00	.63	.81	242	242	16	6	115
Average		.57	.69	243	257	10	7	103

TABLE NO. 11 (Continued)

Boilers Nos. 1 and 2

Time From	Time To	Flue Gas Temp. °F.	Flue Gas Analyses Per cent by volume Co.2	O	Co.	N	Air Excess Per cent
9:00	9:30	450	9.3	10.0	0.0	80.7	89
9:30	10:00	445	9.8	9.5	0.0	80.7	81
10:00	10:30	525	10.5	8.6	0.0	80.9	68
10:30	11:00	505	11.2	7.8	0.0	81.0	58
11:00	11:30	495	10.8	8.7	0.0	80.5	70
11:30	12:00	465	10.2	8.8	0.0	81.0	71
12:00	12:30	480	5.5	14.5	0.0	80.0	223
12:30	1:00	495	8.1	11.3	0.0	80.6	114
1:00	1:30	465	11.2	6.8	0.3	81.7	47
1:30	2:00	535	11.5	7.0	0.0	81.5	48
2:00	2:30	510	8.2	11.6	0.0	80.2	122
2:30	3:00	445	8.0	11.7	0.0	80.3	124
3:00	3:30	450	10.8	8.3	0.0	80.9	64
3:30	4:00	455	10.9	7.9	0.0	81.2	59
4:00	4:30	455	11.1	8.3	0.0	80.6	65
4:30	5:00	485	10.1	8.7	0.0	81.2	69
Average		479	9.8	9.4	0.0	80.8	86

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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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TABLE NO 111 A.

Test of Coal Consumption and Firing Operations.

	August 15
Coal Consumption	
1. Duration of test, hours	10.25
2. Total weight of coal consumed, pounds	65,921
3. Total weight of coal consumed, tons£	32.96
4. Weight of coal burned per hour, ton £	3.22
5. Weight of coal burned per hour per fireman, pounds (?)	16.08
6. Weight of coal burned per hour per fireman, tons £ (?)	0.804
7. Weight of coal burned per hour per boiler, pounds	1,286
Firing Operations	
8. Total number of firings	287
9. Total number of firings per boiler	57
10. Number of firings per boiler per hour	5.7
11. Average interval between firings, minutes	10.5
12. Total number of levelings, slicings, etc.	276
13. Total number of levelings, slicings, etc. per boiler	55
14. Total number of levelings, slicings, etc.,per boiler per hour	5.5
15. Average interval between levelings, slicings, etc.,minutes	10.4

£ Tons of 2000 pounds

TABLE NO 111 B

Firing Operations

August 15

Time From	Time To	Boiler No.1 Firing O.	D.	Slicing and Leveling O.	D.	Boiler No. 2 Firing O.	D.	Slicing and Leveling O.	D.	Boiler No. 3 Firing O.	D.	Slicing and Leveling O.	D.
1:25	2:25	7	12	2	5	6	12	3	5	5	11	3	5
2:25	3:25	5	9	3	7	4	5	5	7	5	6	4	7
3:25	4:25	5	8	5	10	5	9	4	6	6	9	4	7
4:25	5:25	3	5	7	10	7	11	9	16	8	12	9	14
5:25	6:25	9	12	12	17	7	14	5	8	3	4	8	12
6:25	7:25	8	12	8	13	5	8	6	8	9	16	10	15
7:25	8:25	4	6	4	5	4	6	8	13	6	9	5	8
8:25	9:25	5	8	8	12	9	14	6	10	5	6	7	11
9:25	10:25	5	9	8	11	4	5	4	7	5	5	4	6
10:25	11:25	6	6	6	9	6	9	5	7	6	8	7	11
Average per hour-		5.7	8.7	6.3	9.9	5.7	9.3	5.5	8.7	5.8	8.6	6.1	9.6

O - Number of Operations
D = Number of Doors.

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]

[illegible]

[illegible]

TABLE 111 B (continued)

Firing Operations

August 15

Time From - To		Boiler No. 4 Firing O.	D.	Slicing and Leveling O.	D.	Boiler No. 5 Firing O.	D.	Slicing and Leveling O.	D.
1:25	2:25	4	6	3	5	5	9	2	4
2:25	3:25	4	7	4	8	4	6	2	4
3:25	4:25	7	10	4	6	6	10	3	5
4:25	5:25	7	10	6	14	8	13	6	15
5:25	6:25	5	8	6	9	7	12	6	9
6:25	7:25	7	12	9	12	5	9	7	9
7:25	8:25	5	9	6	10	6	7	4	6
8:25	9:25	7	9	6	9	6	9	4	6
9:25	10:25	6	10	4	7	3	4	4	7
10:25	11:25	6	9	6	8	7	8	5	7
Average per hour		5.8	9.0	5.4	8.8	5.7	8.7	4.3	7.2

O = Number of Operations

D = Number of Doors

TABLE NO. 111 C

August 15

Time	Number of boilers with safety valves open	Safety valves open, minutes
1:30	1	6.0
2:00	1	7:5
2:23	2 £	13.0
2:43	3	14.5
3:16	4	7:5
4:40	1	3.0
9:08	1	Less than 1 minute
9:37	1	3.0
11:12	1	2.5
11:35	1	1.5

Total time safety valves were open, minutes	58.5
Duration of test, hours	10.25
Percentage of time safety valves were open	9.5
Maximum period safety valves were open, minutes	14.5

£ Firemen sliced fires with safety valves open.

TABLE NO. 1V

Tests showing Steam Distribution

ENGINES

Harris Corliss Engine No. 1 (12 1/4 x 36)

Conditions:

Date	Aug. 22
Steam pressure, lbs. per sq. in.	105
Revolutions per minute	83
Indicated horse power developed	73.7
Steam consumption per I.H.P. per hr. lbs. (assumed)	40

Results:

Approx. steam consumption per hour, lbs.	2948

Harris Corliss Engine No. 2 (16 1/8 x 42)

Conditions:

Date	Aug. 22
Steam pressure, lbs. per sq.in	105
Revolutions per minute	76
Indicated horse power developed	87.8
Steam consumption per I.H.P. per hour, lbs. (assumed)	40

Results:

Approx. steam consumption per hour, lbs.	3512

Fitchburg Engine (16 x 24)

Conditions:

Date	Aug. 23
Steam pressure, lbs. per sq. in.	123
Revolutions per minute	200
Indicated horse power developed with wood room on	295.5
Indicated horse power developed with wood room off	236.8

Results:

Approx. steam consumption per hour with wood room on, lbs.	8274
Approx. steam consumption per hour with wood room off, lbs.	6630

[illegible]

TABLE NO. 1V. Cont.

Steam consumption per I.H.P. per hour, lbs.	28

Filer & Stowell (1 - 20 x 42, 1-20 1/8 x 42)

Conditions:

Date	Aug. 22
Steam pressure	100-110
Revolutions per minute	98
Total indicated horse power on day load	574
Total indicated horse power on night load	712

Results:

Approx.steam consumption per hour with day load, lbs.	23,650
Approx. steam consumption per hour with night load, lbs.	29,330
Steam consumption per I.H.P. per hour, lbs.	41.2

SODA DIGESTERS

Conditions:

Digester	No.10
Date	Aug. 28
Duration of cook, hours	10
Charge	Poplar chips
Approximate weight of bleached pulp obtained, lbs.	3,485
Average steam pressure	105

Results:

Total steam consumption, lbs.	12,227
Steam used for cooking, lbs	9,130
Steam used for discharging, lbs.	3,097
Steam consumed per lb. of bleached, lbs.	3.51

SULPHITE DIGESTERS

Conditions:

Digester	No. 7
Date	Aug. 22
Duration of cook, hour	10 1/2
Charge	Spruce chips
Approximate weight of bleached pulp obtained, lbs.	1831
Average steam pressure at meter,lbs. per sq.in.	73

TABLE NO. 1V--Continued

Results:

Total steam consumption, lbs.	8,027
Steam consumed per lb.of bleached pulp, lbs.	4.38

YARYAN EVAPORATOR

Conditions:

Date	Aug. 28
Duration, hours	2.75
Initial temperature of liquid, °F	125°
Initial specific gravity of liquid	1,0661
Final specific gravity of liquid	1,2608
Average steam pressure, lbs. per sq.in.	40
Vacuum on evaporator, inches of Hg.	22
Liquor entering evaporator per hour, lbs.	7014.5
Pounds of water evaporated per lb.of steam (assumed)	2.4

Results:

Average steam consumption per hour, lbs.	2045
Steam consumed in evaporator per pound of bleached soda pulp (assuming 4 cooks of average weight 3485 lbs. bleached pulp per 24 hours), lbs.	5.87

BLEACH TANKS

Conditions:

Date	Aug. 10
Duration of test, hours	2 1/3
Charge	Wood Pulp
Approximate weight of bleached pulp (sulphite)	3846
Average steam pressure, lbs. per sq.in.	103

Results:

Total steam consumption, lbs.	1974
Steam consumed per tank, lbs	987
Steam consumed per lb. of wood pulp, lbs.	0.51

PAPER MACHINES

Conditions:

Date	Aug. 25
Duration of test, hours	7
Machines tested	Nos.1 and 2
Diameter of dryers,inches	28
No. of dryers on No.1 using live steam	5
No. of dryers on No.2 using live steam	5

TABLE NO. 1V. Continued

No. of dryers on No. 1 using exhaust steam	8
No. of dryers on No. 2 using exhaust steam	10
Rate of paper per hour for two machines, lbs.	1262
Average steam pressure, lbs. per sq.in.	113

Results:

Average live steam consumption per hour, lbs.	3468
Average live steam consumption per lb. of paper, lbs.	2.7
Approximate exhaust steam used per hour (computed from assumed engine consumption), lbs.	3512
Approximate exhaust steam used per pound of paper (computed from assumed engine steam consumption), lbs.	2.78
Total live and exhaust steam consumed per pound of paper, lbs.	5.53

Conditions:

Date of test	Sept. 3
Duration, hours	5 1/3
Machines tested	Nos. 3 and 4
Diameter of dryers, inches	36
No. of dryers on No. 3 using live steam	20
" " " " " 4 " " "	4
" " " " " 3 " exhaust steam	0
" " " " " 4 " " "	10
Average steam pressure, lbs. per sq.in.	105
Rate of paper per hour for No. 3 machine, lbs.	651
" " " " " " " 4 " "	486
" " " " " " two machines, lbs.	1137

Results:

Approximate steam consumption of No. 1 Harris Corliss engine per hour, lbs.	2948
Average live steam consumption per hour for Nos. 3 and 4 paper machines on No. 1 Harris Corliss engine, lbs.	4756
Live steam consumed by Nos. 3 and 4 paper machines per hour (by difference), lbs.	1808
Live steam consumed per pound of paper, lbs.	1.59
Total live and exhaust steam per pound of paper, lbs.	4.18

TABLE NO. V

Steam Distribution

1. PULP MILL	
a. Fitchburg engine with wood room load, lbs. per hour	8274
b. " " without " " " " " "	6630
c. Yaryan evaporator, lbs. per pound of bleached pulp	5.87
d. Soda digesters, lbs. per pound of bleached pulp	3.51
e. Sulphite digesters, lbs. per pound of bleached pulp	4.38
f. Screens, approx. lbs. per minute of blowing	8.5
g. Bleach tanks, lbs. per pound of wood pulp	0.51
h. Chemical tanks, lbs. per tank per hour	1151
i. Lime tanks	
11. PAPER MILL	
a. Small Harris Corliss engine, lbs. per hour	2948
b. Large Harris Corliss engine, lbs. per hour	3512
c. Paper machines Nos. 1 and 2, lbs. per lb. of paper	5.53
d. " " " 3 " 4 " " " " "	4.18
111. COATING MILL	
A. Filer & Stowell engine, day load	23650
night load	29330
b. Drying coils	

TABLE NO. V1

COST OF STEAM

July and August

1. INVESTMENT GROUP

	Cost	Rate %	Charge	
A. Amortization				
1. Building	$19,986.	1.3	$260.	
2. Stack	7,000.	1.9	133.	
3. Flues	2,700.	4.8	130.	
4. Boilers and settings	17,500.	4.8	803.	
5. Economizer	1,855.	4.8	120.	
6. Heater	2,160.	4.8	104.	
7. Pumps	1,800.	3.8	68.	
8. Piping	13,500.	8.1	1094.	
9. Damper regulator	58.	8.0	5.	
10. Furniture	80.	8.0	6.	
Total	$66,639		$2723.	$2,723.
B. Interest (5% of investment)				3,332.
C. Taxes (0.8% of investment)				533.
D. Insurance (0.1% of investment)				67.
E. Boiler insurance				156.
F. Land value	5,531			
Interest (5% of investment)				277.
Taxes (0.8% of investment				44.
				$7,132.

TABLE NO. V1. Continued

11. PRODUCTION AND PRODUCTION REPAIR COSTS		
A. Labor		
1.Engineer (@$2,000 per year)	$2,000.	
2.Engineer (3 men @ $17.50 per week)x 52 (9 " @ $16.80 " ")	10,592.	
3.Coal passers (6 @ $12.25 per week)x 52	3,822.	
4.Coal handlers (6 @ 1.50 per day) x 300	2,700.	
Total		$19,114.
B. Fuel (21,000 tons @ $4.51)		94,710.
C. Repairs (2% of investment)		1,333.
D. Supplies		500.
Total		$115,657.
Total of investment group and production and production repair costs		$122,789.
111 COST OF EVAPORATION.		
1.Fuel consumption per year, tons		21,000.
2.Heating value of fuel per pound, B.t.u.		13,400.
3.Approximate proportion of heat in fuel utilized in evaporating water, per cent		70
4.Total equivalent evaporation per year from and at 212 °F. under atmospheric pressure, lbs.		446,500,000
5.Factor of evaporation under assumed average conditions of 100 lb. gage steam pressure and 245 °F.feed water temperature		1,006
6.Total actual evaporation per year, lbs.		443,800,000
7.Total cost of evaporation per year		4 122,789
8.Cost of evaporating 1000 lbs. of water under assumed conditions		$ 0.2767

Test of Gebhardt Steam Meter on six inch Inlet Steam Pipe to 750 K.W. Curtis Steam Turbine.

Steam pressure, lb. per sq. in.	162	163	161	162	162	163
Steam temperature, °F.	393	393	393	393	401	411
Temperature of saturated steam at observed pressure, °F.	365	365	364	365	365	365
Degrees of superheat, °F.	28	28	29	28	36	46
Temperature of circulating water, °F Inlet	88	88	88	88	88	88
Outlet	98	98	97	97	99	99
Vacuum, inches of Hg.	27	27	27	27	26 7/8	26 7/8
Av. observed reading on meter chart	614.4	617.4	615.3	615.6	695.6	703
Steam consumption computed from meter reading, lb. per hr.	13,874	13,990	13920	13,920	15,706	15,706
Steam consumption by actual weight, lb. per hr.	13,932	13,980	13,896	13,920	15,540	15,540
Correction factor for meter reading	1.0042	.9992	.9982	1.0000	.9896	.9896

Average correction factor for meter .9951 Maximum variation .0104

PHOTOGRAPH NO. 1

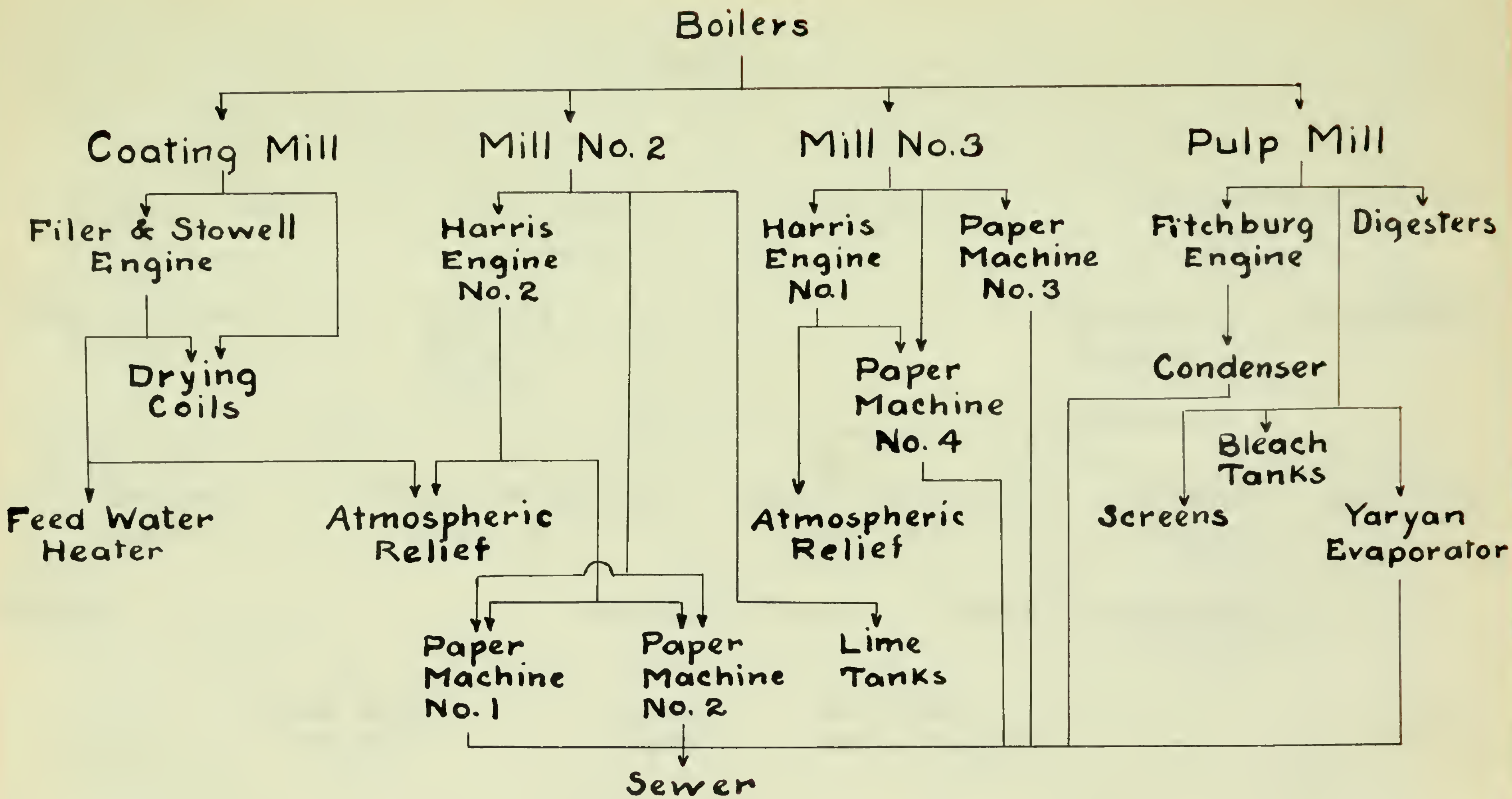
Exterior View of Boiler Plant

PHOTOGRAPH NO. 2

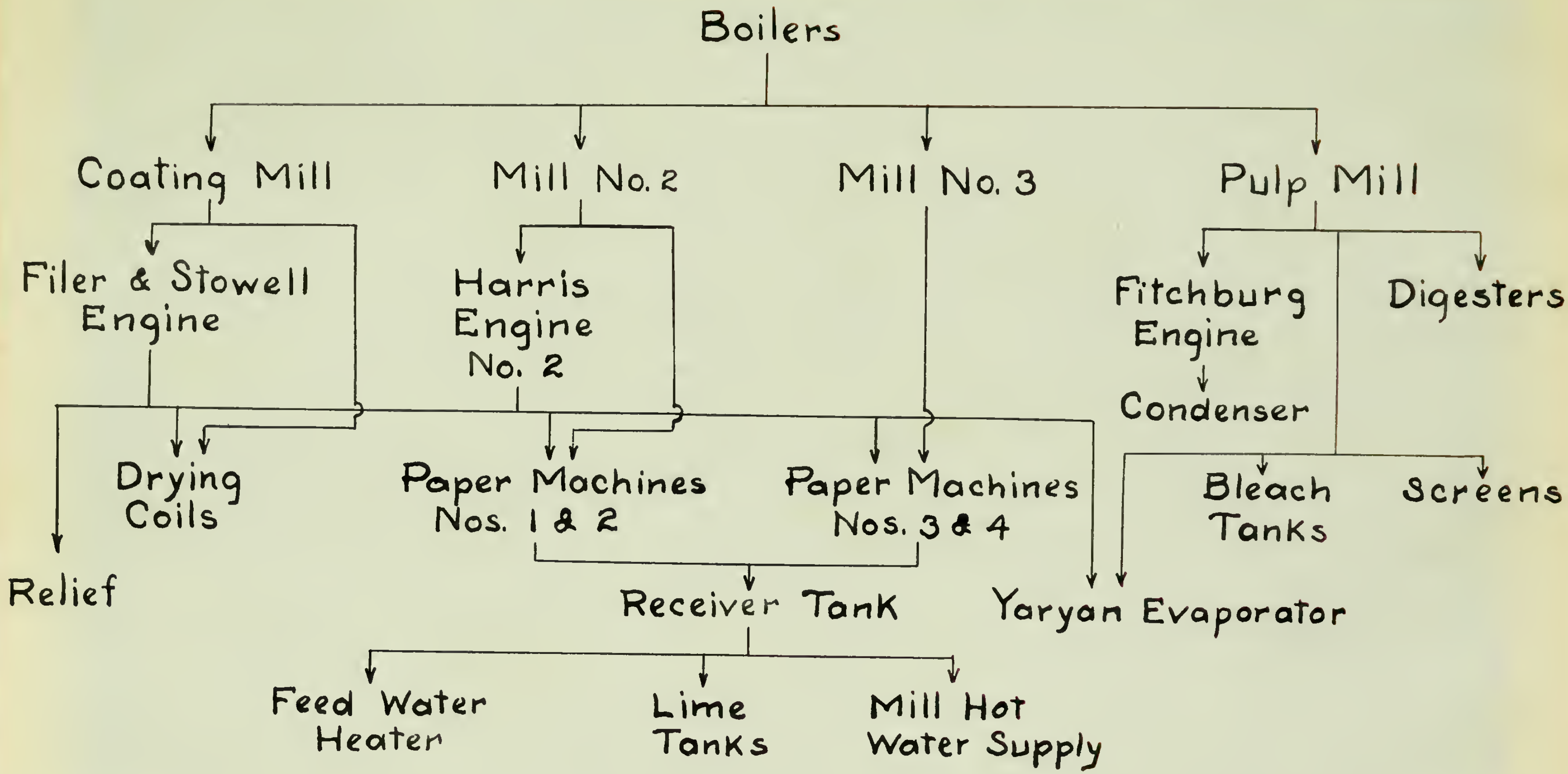
Interior View of Boiler Plant

PHOTOGRAPH NO. 3

View showing arrangement of Closed Feed Water Heater and Feed Pump.



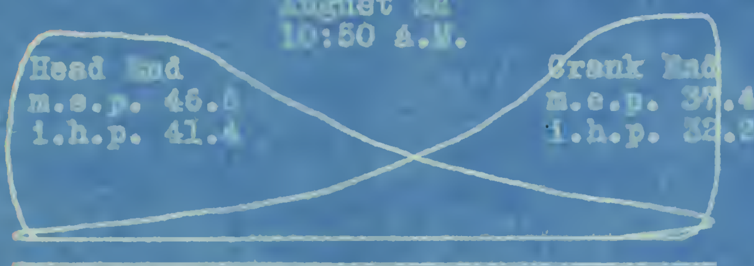
STEAM DISTRIBUTION



PROPOSED STEAM DISTRIBUTION

Indicator card taken from No. 1
Harris non-condensing Corliss engine.
12 1/4 x 36 inches.

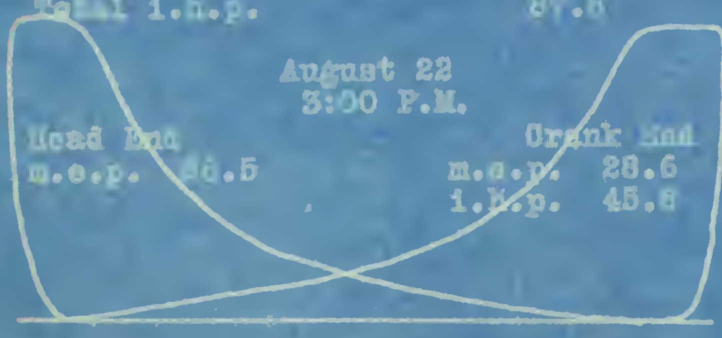
Diameter of rod	2 1/16 inches
R.p.m.	83
Total I.h.p.	73.7



Scale of spring 80

Indicator card taken from No. 2
Harris non-condensing Corliss engine
16 1/8 x [illegible] inches

Diameter of rod	2 5/8 inches
R. p. m.	7[illegible]
Total i.h.p.	[illegible]



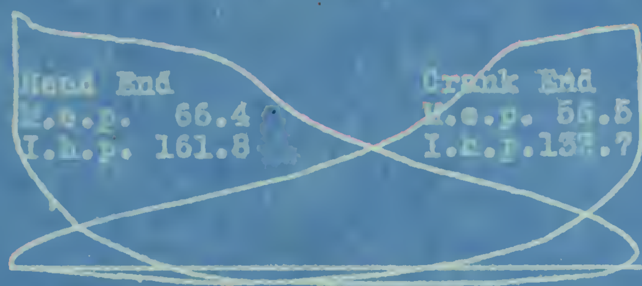
Scale of spring 60

Indicator cards taken from Fitchburg high speed condensing engine.

15 x 24 inches

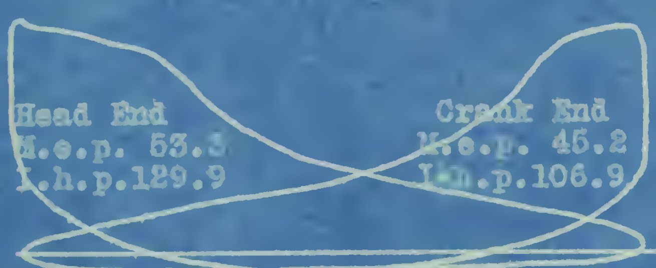
Diameter of rod 2 3/4 inches
R.p.m. 200

With wood room on
Total i.h.p. 295.5



Scale of spring 90

With wood room off
Total i.h.p. 236.8



Scale of spring 90

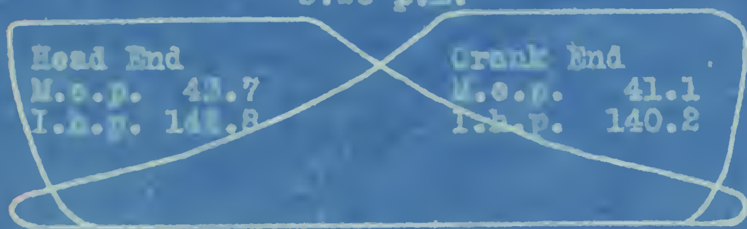
Indicator cards taken from Filer & Stowell twin non-condensing engine.

Date.	August 22
Diameter of right cylinder	20 inches
Diameter of left cylinder	20 1/8
Diameter of rods	3 1/4
Stroke	42
R.p.m.	98

RIGHT CYLINDER

Total i.h.p.	283
Electrical load	171.8 K.W.

5:26 P.M.

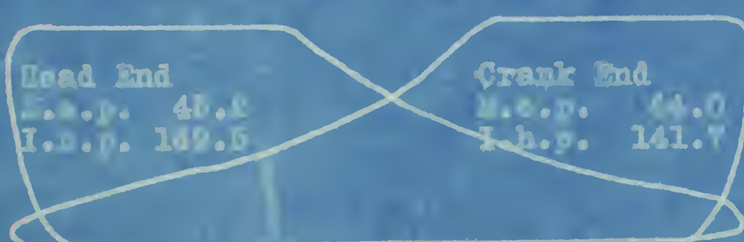


Scale of spring 60

LEFT CYLINDER

Total i.h.p.	291
Electrical load	170.8 K.W.

4:18 P.M.



Scale of spring 60

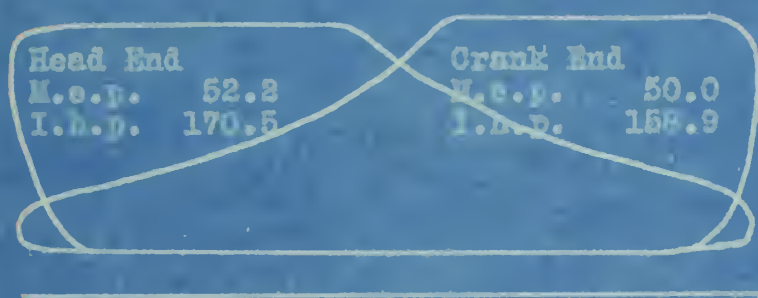
Indicator cards taken from Filer & Stowell
twin Corliss non-condensing engine

Date	August 26
R.p.m.	98

RIGHT CYLINDER

Total i.h.p.	329
Electrical load	302.4 K.W.

8:25 P.M.

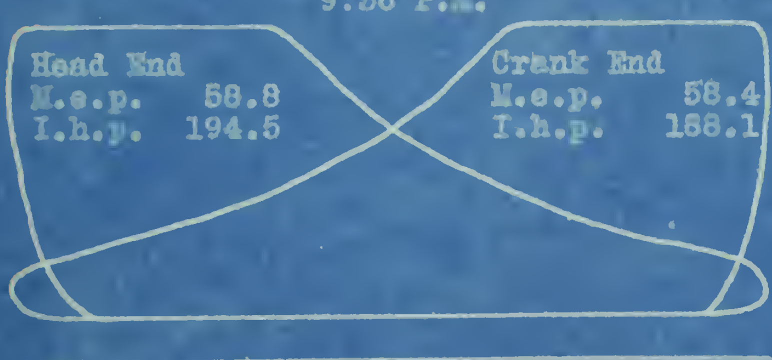


Scale of spring 60

LEFT CYLINDER

Total i.h.p.	383
Electrical load	302.4 K.W.

9:36 P.M.



Scale of spring 60